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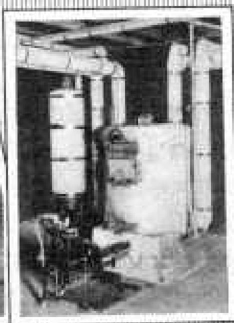
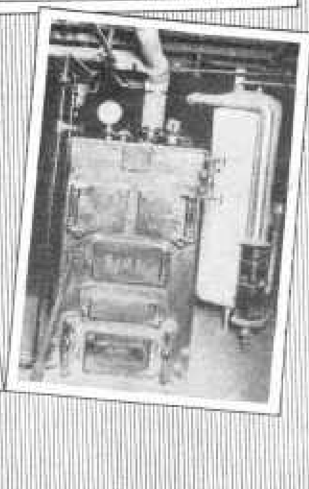



OPERATING A HOME HEATING PLANT

MODERN heating equipment is now used in many farm homes. A large proportion of these installations are burning more fuel than they should or are not heating the house satisfactorily. This may be due to the selection of a plant of the wrong design, size, or type, faulty installation, poor operation, or to loose-fitting doors and windows. In this bulletin the requirements that should be met in order to heat the home satisfactorily are discussed and advice is given concerning the selection, installation, and operation of home-heating plants.

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OPERATING A HOME HEATING PLANT.

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CONTENTS.

REQUIREMENTS FOR SATISFACTORY HEATING.

THE satisfactory and efficient heating of homes requires, first, that the chimney flue be of the proper size and in the proper place; second, that a proper heating equipment be installed correctly; third, that the plant be understood thoroughly and operated in a manner to give the maximum return from the fuel consumed; fourth, that the house construction be so tight that heat is confined within and cold air kept out; fifth, that the air be kept humidified as near to the correct degree as possible; and, sixth, that fresh air be admitted either continuously or from time to time in sufficient quantity to obtain the proper carbonic acid diminution.

Atmospheric conditions in our homes are seldom maintained as they should be. Houses are often overheated. In most cases practically no thought is given to humidity or to air moistening. Physicians insist that an overheated house is unhealthy, and that colds, sore throats, coughs, and the tendency to be nervous and feverish may be attributed to continually breathing air having too low a moisture content.

To overheat a house is a wasteful practice. It means the consumption of more fuel than is necessary. It shows a lack of knowledge of the apparatus and of its proper handling, for which the owner pays in dollars and cents. In certain sections of our country climatic conditions often change rapidly from extremes of heat to extremes of cold. Under such conditions one can not be too well versed in the characteristics of his heating system.

To live in too dry an atmosphere promotes ill health and augments the doctor's bill. It means neglect of an important phase of home conditions—lack of appreciation of atmospheric conditions as found in nature. Statistics show that about one-third of all deaths in this country have been due to diseases of the throat and lungs. Fresh, clean, pure, humid air as found out of doors is the treatment generally prescribed for such ailments; and until we understand the advantage of properly humidified homes we must expect the recurrence of discomforts that largely disappear during the seasons when our doors and windows are kept wide open. While this bulletin applies particularly to homes heated by warm air, hot water, or steam plants, many of the suggestions apply equally well where stoves are used.

THE CHIMNEY FLUE.[1]

Chimneys defective in construction or badly located cause many failures of heating systems. Air passes up the chimney flue with a spiral movement; therefore a round, smooth flue is preferable because it offers less resistance to the upward passage of the gases. For structural reasons and because of the increased cost it is not nearly so common as the square or rectangular flue. The square is preferable to the rectangular. Many chimney flues are not lined. That is a mistake. The first cost of a lined flue is greater, but the benefit is not only better furnace operation but continual fuel saving; moreover the danger of fire is lessened.

The most efficient chimney, as far as draft is concerned, is one built perfectly straight from the bottom up with a round or nearly round flue, lined with tile or having the interior surface made smooth by other means. There is no advantage in tapering the inside toward the top. The cross section and height are determining factors of efficient service. The transverse area must be sufficient to pass the volume of air required to burn the fuel properly, and the height must be great enough to produce sufficient draft and insure against interference by adjoining buildings or projections of the same building.

In a square or rectangular chimney the corners are dead. The effective area in square flues is 85 to 90 per cent, and in rectangular flues about 75 per cent.

Ordinary residence chimneys vary in height from 25 to 60 feet, their area being proportional to the size of the house. A chimney large enough for the draft may yet be too small, for no flue should be less than 8 inches in diameter or 8 inches square. Satisfactory results can be expected under ordinary conditions with warm air, hot water, or steam plants if the sizes given in the following table

[1] Farmers' Bulletin No. 1230, Chimneys and Fireplaces, will be of interest to those about to build and to those whose heating plants are unsatisfactory.

are followed. The sizes given are the commercial designations, the actual sizes of the flues being a little less:

Flue sizes for residences.

Volume of building.	Size of flues.		
	Round.	Square.	Rectangular.
Cubic feet.	*Inches.*	*Inches.*	*Inches.*
20,000	8	8 by 8	6 by 10
40,000	9	9 by 9	8 by 12
60,000	10	10 by 10	8 by 14
110,000	12	12 by 12	10 by 18

SELECTION AND INSTALLATION OF HEATING EQUIPMENT.

The selection of the system to be purchased should be made with the greatest care and only after a thorough investigation of its suitability to the house for which it is intended.

Efficiencies of heaters, as advertised, have been determined under laboratory test conditions. Theoretically, when a selection is to be made the best results would be expected from the heater which shows the highest efficiency rating, and if it were possible to base a selection upon data secured under identical test conditions the test results would be a fair indication of the relative efficiency. But there are other factors that affect the results.

The term efficiency applied to the maintenance of inside temperatures or to economy of operation of house-heating equipment may be misleading. All heat energy made available by a heating apparatus is ultimately transmitted to the outer air. The walls of the building, the windows, doors, etc., interpose resistance between the heated space and the outer air. If these are poor conductors of heat then the resistance is relatively high, and a higher temperature will be maintained in the room with the same flow or radiation of heat than if they were good conductors, hence the efficiency of heating equipment can be but relative.

Consequently, the heating plant with highest efficiency for a particular house must be judged by service to the owner. It will be the plant that gives the best service at the least cost. As individual demands and requirements differ, so opinions of users as to results from different plants will differ. Adequate service is the first requisite. If several will give this then the selection depends largely upon the comparative cost. If the cost does not affect the selection, then reliability and convenience of operation should be the determining factors.

Do not rely upon the judgment, opinion, or experience of any one person unless that person is familiar with all equipments and un-

biased. Talk with owners of different plants, learn the disadvantages of their installation, and find out whether all the rooms are heated satisfactorily. If they are not, try to find out whether the fault lies in the unsuitability of the apparatus to the particular house or to improper installation or poor operation. If the owner seems satisfied, before you decide on similar equipment, assure yourself before placing the contract either that the plan of your house is essentially the same or that the system can give satisfactory results with either type of construction.

THE HEATER.

After deciding on the type of apparatus be sure that the heater is of sufficient size to heat the building easily in the coldest weather. Consider service above price and appearance. Make a selection based on reputation, economy of fuel, and attention required for operation. Examine the joints to see that proper provision has been made for contraction and expansion, see that the castings are well made, free from large blowholes, cracks, or other imperfections. Inquire whether the manufacturer is reputed a maker of good heaters.

INSTALLATION.

The best and highest-priced heater improperly installed may give less satisfactory results than the poorest and cheapest properly installed. Therefore consider well the competency of the man who is to do the work. He should have had experience in putting in similar equipment, should be one that is in touch with the manufacturer directly or through a representative; above all a man who takes pride in doing good work. Having made a wise selection, realize that it is the business of the contractor to put in a successful plant and to his interest. Therefore do not dictate to him unless you are prepared to assume responsibility for the result. If locations which he proposes do not agree with your wishes, make sure that your choice will not affect the results.

Heating contractors expect to guarantee that the apparatus will heat certain rooms to a definite temperature under specified outside conditions. The purchaser should ask for such a guarantee.

UNDERSTANDING THE HEATER AND OPERATING IT INTELLIGENTLY.

To warm a house at low cost the characteristics of the heater must be understood and it must be operated intelligently. One who looks upon every heating apparatus as merely a mechanical contrivance which he has but to fill with fuel and remove ashes from in order to provide comfortable rooms for his family will fail. Some

mechanical apparatus may be almost wholly automatic in its action, but a domestic heating apparatus is not in this class. Its action must be controlled and its functions to some extent directed. All persons can not be expected to understand the technical details of heating problems, but it is in the interest of every owner to become as familiar as possible with the operation of the heating plant upon which he depends during the winter months.

It is not enough to install a heater, fill the bins with coal, and then expect it to do the business. Nor can economy be practiced and proper temperatures be maintained if a servant that has no interest in the annual coal bill be given free rein.

Waste should be eliminated. The heat locked up in every pound of coal that goes into a heater should be extracted. The ash can should contain no combustible. If it is possible with a certain coal consumption to maintain a comfortable temperature, to burn more is extravagance and waste. The average house owner burns too much coal, principally because he does not know how to regulate his heater.

Heaters should be studied in relation to the work that they are to do. Every owner should know how to regulate his furnace so as to make it follow the changes in the outside temperature.

REGULATING DAMPERS.

In figure 1 the common location of dampers and checks is shown, although they are frequently placed in other places. While the illustration shows a warm-air furnace, the following explanation of the use of dampers applies equally well to any type. Four dampers should be provided. They are customarily referred to as the draft damper, the check damper, the feed-door damper, and the smoke-pipe damper. The draft damper is generally a lift door or slide in the ash-pit door through which nearly all the air that makes the fire burn is admitted. The check damper is usually located at some point in the smoke pipe, not necessarily as shown in figure 1. By opening this damper, cold air is admitted into the smoke pipe, interfering with the chimney draft, and retarding the burning of the fuel in the heater. This damper should be closed tight when fresh coal is added to the fire. It is convenient to have a chain connected to it and run through the floor above, so that it may be operated without making a trip below, though with this arrangement inspection of the condition of the fire is impossible and there is the chance that it will not receive the attention it should. The feed-door damper, consisting of a slide in the feed door, is of more importance than is usually supposed; through it cold air is admitted directly

over the fire; if opened wide it acts as a check, similar to the check damper; if the opening is properly regulated it admits just sufficient air to supplement that admitted through the draft damper, causing more perfect combustion of the fuel. The fourth damper, known as the smoke-pipe damper, is particularly valuable for a chimney with an exceptionally strong draft, as it gives more effective control than can be obtained with a check damper only, in windy weather or at night; this damper is frequently omitted, sometimes without detriment, but it is best that it be provided, and it should always be placed between the furnace and the check damper and never between the check damper and the chimney flue.

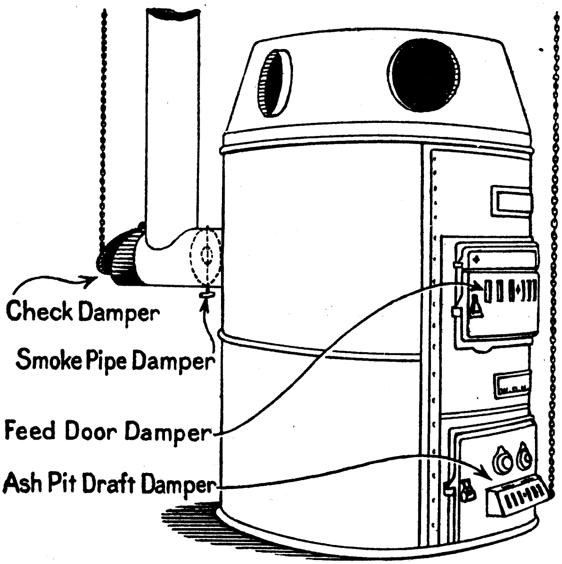

FIG. 1.—Location of furnace dampers.

Another damper, known as the hot-blast damper, is provided for soft-coal furnaces. This draft opening connects with an independent air chamber for admitting heated air above the fire. Its function is essentially the same as that of the feed-door damper, differing from it only in extent.

OPERATING THE DAMPERS.

When a fire is to be started, after preparing the firepot with light material and placing a little heavier wood on top, open the draft damper wide, close the check and the feed-door dampers, and set the smoke-pipe damper so that the wood fire burns briskly but not too fast. When the wood is burning thoroughly, throw on coal, spreading it well over the burning mass of wood. Do not put on too much coal at one time. See that the fire continues to burn well. If blue flames are noticed sprouting up over the coal when the feed door is opened, then open the feed-door damper to admit additional air to burn the gases that are being given off from the coal. When the blue flames disappear close the feed-door damper and permit the fire to burn up until the temperature of the house has about reached that desired. Then close the draft damper and open the check

damper until the fire seems to stand still. It may be found necessary to keep the draft damper slightly open. The owner should experiment with these two dampers to determine just how far each should be opened to hold the fire so that the desired temperature in maintained in the rooms.

When the fire is to be closed down for the night, after having thrown on fresh coal or banking cinders, close the check damper and open the draft damper, allowing them to remain so until gases cease to be given off, indicated by the disappearance of blue flames over the coals; then close the draft damper and open the check and the feed-door dampers. Sometimes it may be advisable to close the smoke-pipe damper completely. This must be determined for each installation, as it is dependent upon the chimney draft and the weather.

There is another factor that affects the damper operation. Different kinds or grades of coal require different quantities of air for combustion, and consequently a damper must be opened just wide enough to burn the coal most economically.

SELECTION OF FUEL.

Let it not be assumed that one grade of coal will be as satisfactory as any other. The best fuel, that which will require the least attention in burning, will be the most economical and will give the greatest satisfaction. Sometimes poorer coal may have to be used, as was the case in many domestic heating systems during the war, when transportation problems compelled the use of poorer grades.

Fuels for house-heating purposes may be mentioned in the order of their desirability as follows: (1) Anthracite coal in sizes commonly known as pea, buckwheat, chestnut, stove, egg, and furnace; (2) gas-retort or metallurgical coke in pieces one-half inch to 3 inches through; (3) coal briquettes, 2 to 3 inches in diameter; (4) screened Pocahontas (semibituminous) coal, over one-quarter inch and up to 3 or 4 inches in diameter; (5) sized bituminous coal in pieces one-half to 3 inches across. Although a good grade of hard coal is generally considered to be preferable to any other fuel for house-heating furnaces, coke may often be found to be more satisfactory than the grade of hard coal obtainable. The smallest size of coke, known as No. 2 nut, running from one-half inch to 2 inches, frequently may be purchased at a price below that asked for the usual furnace sizes, because of the popular impression that it can not be burned successfully on ordinary furnace grates. Investigations have shown this size of coke to be very satisfactory for heating houses and stores. A larger size does not lay so closely, and therefore frequently burns too fast, requiring more frequent firing. It is generally thought that this smaller coke is subject to heavy leakage through the grate bars into

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the ash pit. Excessive shaking would probably produce this result, but a coke fire requires less shaking of the grate than a coal fire. In ordinary weather one shaking a day, preferably in the morning, is all that will be necessary. In very cold weather the grate may have to be shaken before each firing. Better results are obtained with little shaking, and the fire should never be shaken so much that pieces of hot coke fall into the ash pit. Therefore, as soon as sparks appear in the ash pit, stop shaking. Some who have burned coke for years claim better results from leaving a layer of ashes 1 to 2 inches thick on the grate all the time. The ashes check the draft and keep the hot coke from coming in contact with the grate. Although this size of coke clinkers rather freely, the clinker is soft and quickly breaks up. Clinkers should be removed while the fire is hot and before fresh fuel is put on, because under such conditions the ignited coke in the firepot is in a semiplastic state and when distributed by the removal of the clinkers merely settles down in the grate without falling through.

ATTENTION TO THE FIRE.

Generally speaking, comparatively little attention is given the fires in house-heating equipment. In some cases the fire is permitted to vary from one extreme to the other. No attention is paid to it until the house becomes uncomfortably cold or too hot. It should receive attention at regular intervals. Usually the man of the house will attend to it early in the morning, late in the afternoon, and just before retiring with more or less regularity. This enables him to study his fire and fuel and perhaps to judge the relative merits of different fuels used, providing he realizes that only by actual trial in his particular furnace under conditions of customary usage can he learn which fuel is best suited to his requirements.

It is impossible to state how often a fire should receive attention without knowing the actual conditions. The type of heating system has much to do with it. For instance, a hot-water heating system will maintain a far more uniform temperature with less attention to the fire than will a hot-air system. No definite rule can be laid down that will apply satisfactorily in all cases. Thus the attention given to the fire will govern materially the fuel to be used. It is well for every individual to devote the first heating season after installing a heating system to a study of fuels and their burning in his particular heater. Buy at least two kinds of coal at one time and experiment with each separately and mixed in varying proportions. Note their burning qualities, whether they catch quickly, how much ash is left, and what the condition of the ash is, whether one size filters through the grates unburned, whether another forms clinkers that are difficult to remove or fuses and forms a crust that

interferes with the draft. An intelligent owner will soon be able to tell the kind of fuel best suited to his conditions and can then buy accordingly.

A fire should not be shaken down more than three times a day. Generally twice will be found sufficient, in the morning and in the late afternoon. Unless the fire has been burning hard continuously, and fresh coal has been fed to it at frequent intervals, care should be taken not to shake too much. Do not shake live coals through the grate. In mild weather let an accumulation of ashes remain on the grate. Never leave ashes under the grate in the ash pit, but clean out immediately after shaking. The volume of the ash pit is designed to permit enough air to pass into and through it to burn the fuel properly and at the same time keep the grate-bars cool enough to prevent injury from overheating. If ashes are allowed to remain in the ash pit they prevent necessary air circulation, hinder combustion, and cause damage to the grates. Figure 2 shows a set of grate bars removed from a furnace in which ashes had been allowed to accumulate. Note the warping and bending and how too little air will cause the iron to melt.

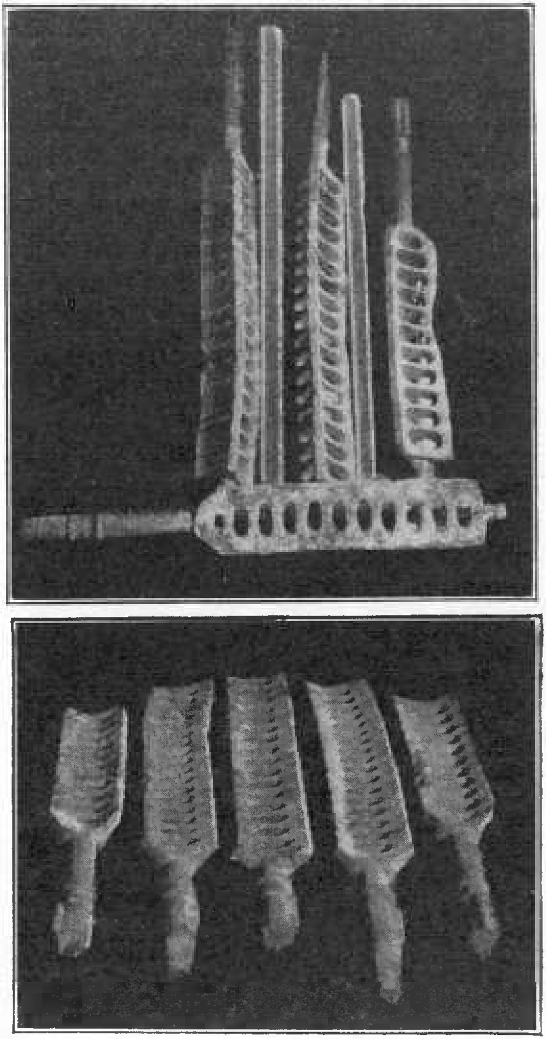

Fig. 2.—Grate bars warped and bent, due to allowing ashes to accumulate in the ash pit.

Do not shake down a fire until it has had time enough to catch. When first attending the fire in the morning it is well to open the

smoke-pipe draft damper and the ash-pit draft damper, throw on a little fresh coal, and allow it to catch well. When it is glowing, or, if one is in a hurry, after the blue flames have stopped flickering through the fresh coal, shake the grate back and forth with a short, quick movement. Do not turn the grates completely over unless it is necessary to remove a large clinker. As soon as the first bright spot is seen through the grate, stop shaking and clean out the ashes, sprinkling them if possible before handling. A small watering pot kept near the furnace assists materially in keeping down dust.

Disturbing the fire by poking or upturning is advised against wherever it will catch up and burn properly if given time. There are occasions, however, when it becomes absolutely necessary to use a poker. Caking or fusing coal demands attention to prevent the formation of a fused noncombustible mass directly over the grate. Considerable trouble from this cause has been experienced by the writer. It was found necessary when the fire was permitted to burn steadily to turn the fire almost completely over twice a day to avoid having to dump it through the grates and rebuild the fire. A mixture of stove and pea anthracite coal had given the most satisfactory results with the least attention. Conditions due to the war made it impossible to obtain the usual grade of these two sizes of coal, with the result that frequent overturning of the fire was necessary. The coal fused and formed a noncombustible mass directly over the grate, as illustrated in figure 3. Unless broken, this covering would so close the draft as to put the fire out or prevent it from burning sufficiently to give heat. Rocking the grates would sometimes break the fused mass, but not always. Sometimes the grates could be revolved with no effect other than to raise the whole mass. It then was necessary to use a poker through the fire door and break the mass by punching a hole through it and lifting the whole fire until the noncombustible mass was brought to the top, where it could be broken to pieces and removed through the fire door. Pieces 15 inches long and 3 inches thick were removed. Samples are shown in figures

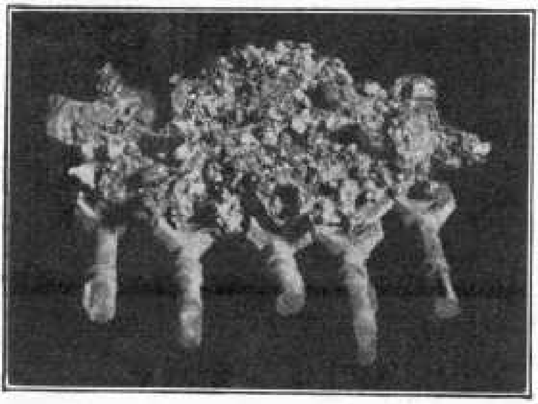

FIG. 3.—Caking coal forming a hard fused mass directly over the grates that practically stops the draft.

4 and 5. The pile (fig. 4) with a 4-foot rule shown in front of it represents an accumulation of 10 days. Until this method was adopted it was necessary to clean the fire completely out about every sixth day. However, if it is resorted to, there must be a good fire on top of the mass. Unless it is turned over before the draft has

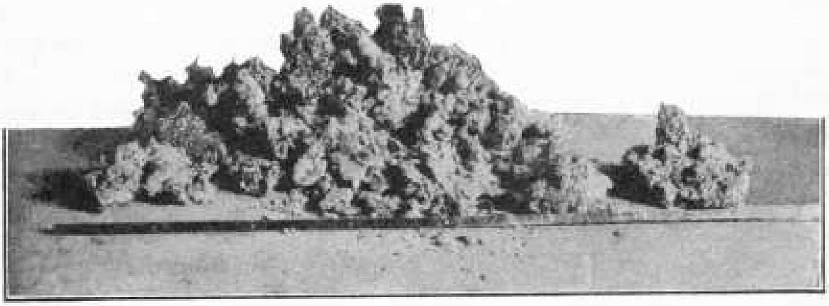

Fig. 4.—Fused noncombustible matter removed through the fire door. This had to be broken daily, the fire overturned, and the clinker removed.

been cut off enough to permit free burning the fire will need to be coaxed with wood, but by having a good bed of live coals when the overturn is made practically no harm will result to the fire. The writer has maintained his own furnace fire for months without permitting it to go out, at the same time heating his house with less

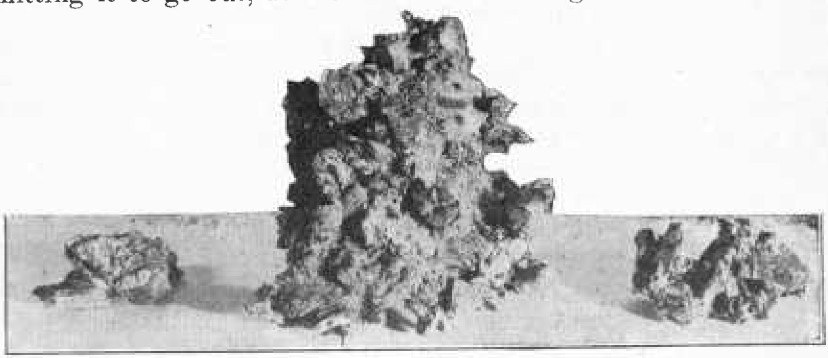

Fig. 5.—Samples of fused combustible formed from a mixture of equal parts of pea and stove size coal in a domestic heater. The largest of these pieces measured 12 by 16 inches.

fuel than neighbors burned with the identical heating system in exactly similar houses.

WEATHER-TIGHT HOUSES ESSENTIAL TO ECONOMICAL OPERATION OF A HEATING PLANT.

WINDOW AND DOOR LEAKAGE.

A change of air in all occupied rooms is essential to health. In residences one complete change an hour is usually considered ade-

quate, and calculations are so figured. Under conditions of moderate temperature and wind in houses of ordinary construction the air change through window and door cracks is not objectionable. Neither does it materially affect the operation of the heating plant. But when snow or rain is driven before a wind of 25 to 60 miles an hour if window and door cracks permit not one air change per hour but often as many as five, so that the atmosphere in the rooms, especially on the windward side, is many degrees below that usually maintained, then it is that the heating plant is often taxed beyond its capacity. Some rooms possibly are then closed off from the rest of the house, and an attempt is made to throw a maximum quantity of heat into one or two rooms—a practice altogether too prevalent. Remedies are numerous; the following may be mentioned: (*a*) Storm sash; (*b*) wood and felt weather stripping; (*c*) strip felting; (*d*) metal weather stripping; (*e*) calking compounds.

STORM SASH.

Storm sash provide an air space between the two layers of glass. This air space has an insulating value which reduces the effect of the cold outside air both as regards chilling the heated air in contact with the glass and leakage around the inner sash. Popular and useful as they are, many persons nevertheless object to their unsightliness. If fixed the value of the window for ventilation is lost; but the sash should be as air tight as possible when completely closed. A home-built one that permits opening at either the top or the bottom on a warm winter day is shown in figure No. 6.

WOOD AND FELT WEATHER STRIPPING.

Wood and felt weather stripping when put on properly aids materially in keeping out cold air. It should be applied on the outside at the opening between window sash and frame for the upper sash and usually to better advantage on the inside for the lower sash. When applied to windows or doors the felt should be placed in such close contact that more than ordinary effort is required to move the window sash and that the door must be pushed hard in order to lock it. Wood and felt stripping may also be used between the frame and wall where the wall line is not too irregular to completely close any crack there. Placed at the bottom of outside doors, wood and felt stripping aids materially in reducing drafts along the floor, a frequent source of colds in young children. The stripping should be attached to the outside of doors opening inward. Drafts under interior doors may be stopped in a similar manner. When first applied this stripping is highly efficient, but may not long remain so.

It tends to loosen from sliding sashes, while continual opening and closing of doors bends the felt back and forth, reducing the stiffness, so that it fails to close the crack completely. To secure the best results from its use on sliding surfaces, it should be reapplied every year, while that used on the bottoms of doors should be inspected and reset when it becomes less efficient. Many object to its unsightliness whether it be put on the inside or the outside.

STRIP FELTING.

Strip felting may be used like the wood and felt stripping. If the wall line adjoining the window or door frame is irregular, the crack may be closed satisfactorily with strip felt. It may be forced in until it is flush. This affords a more sightly appearance than

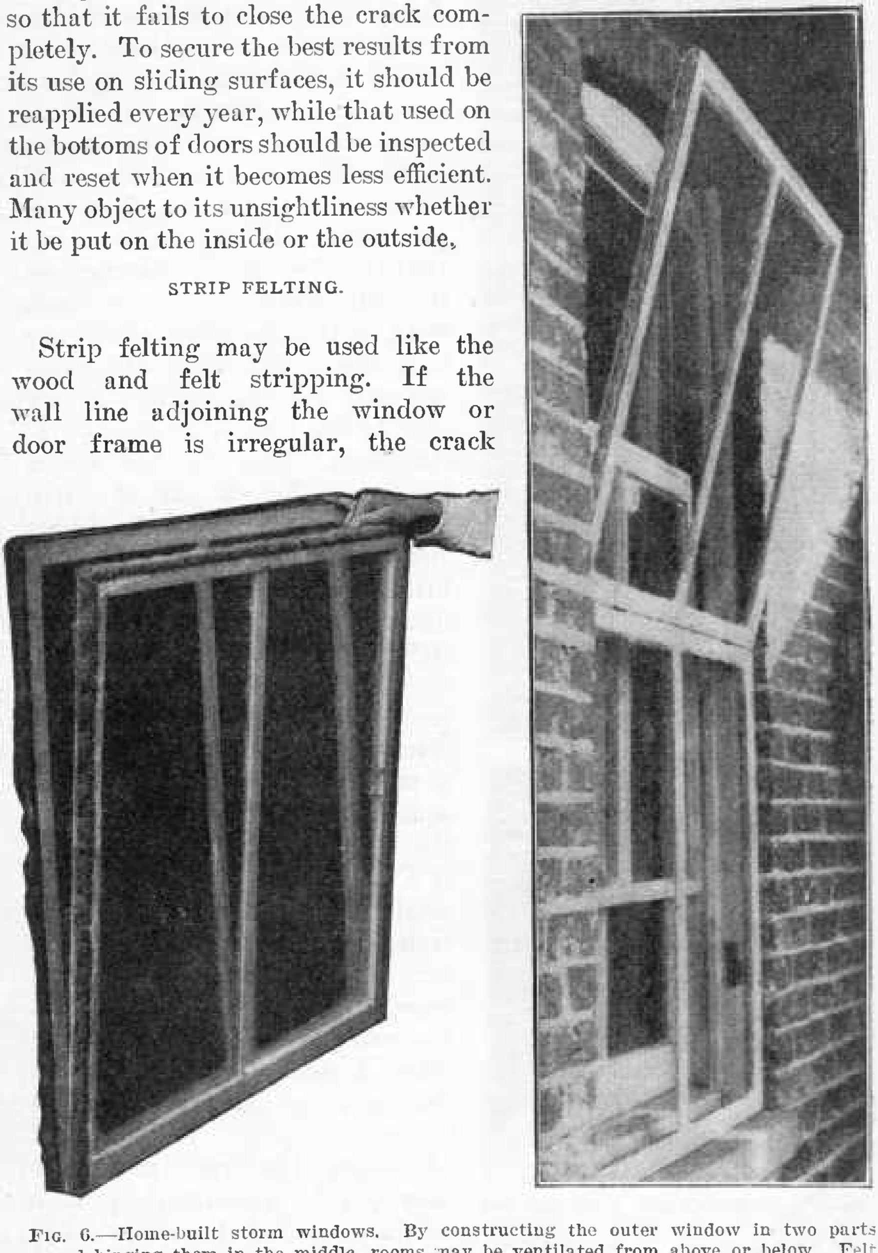

FIG. 6.—Home-built storm windows. By constructing the outer window in two parts and hinging them in the middle, rooms may be ventilated from above or below. Felt is tacked to the inner and side surfaces in order to make a tight joint, and the sections are held in place by screw hooks and eyes on each side.

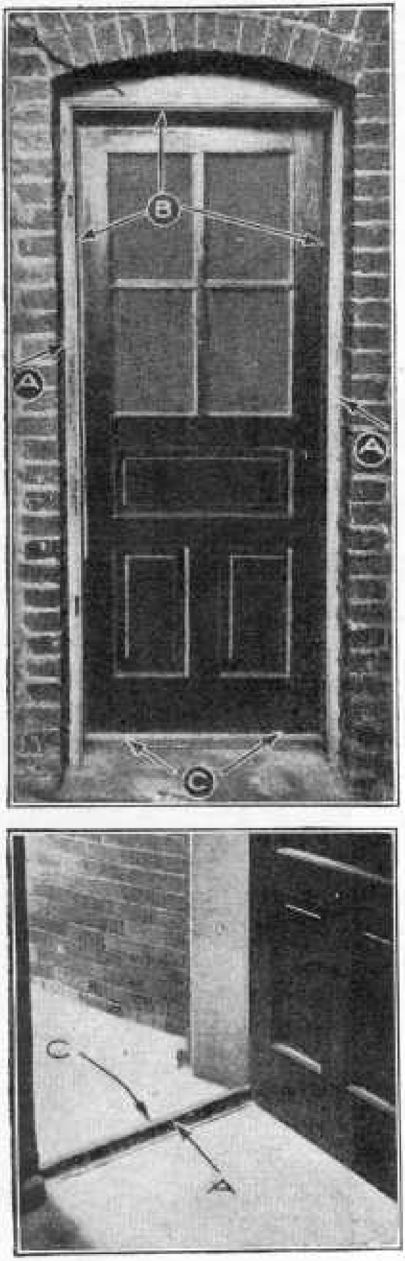

FIG. 7.—Strip felt and wood and felt weather stripping used to advantage in closing cracks. A represents felt tacked so as to cover the crack; B shows location of wood-felt nailed to the frame; and C is a block of wood covered on two sides with felt, placed so as to leave no crack under the door.

where wood and felt stripping is used. As a temporary expedient during short periods of high winds and low temperatures, strip felting may be used on the inside of all windows to close cracks by tacking it around the frame so that it rests against the sash. Thumb tacks mar less than carpet tacks and are more easily removed. Strips of this felt on the sill where the lower sash rests, at the top where the upper sash closes, and along the meeting rail aid materially. It can also be used to close cracks under doors. Note the door shown in figure No. 7. At A strip felting was tacked to the frame and then wedged between the brickwork and door framing. Ordinary wood and felt weather stripping was nailed to the frame, so that when the door is closed no crack is left. To close the crack at the bottom two sides of a strip of wood about one inch square were covered with felt and the strip was placed as shown at C, figure No. 7, and held by a small angle iron and screws on each side. In the above manner all cracks around this door were so effectively closed that no water leaked into the cellar when it stood 12 inches deep in the areaway outside during a heavy downpour. This method of closing the crack under the door may be condemned by some on the score that it forms a stumbling block. The one shown in figure No. 7 has been in place two years with two children between the ages of 4 and 7 using

the passage continually. Neither as yet has stumbled over the block. While strip felting may be used for advantage and in some instances in a more or less permanent fashion, yet it must in general be considered a temporary expedient. Its unsightly appearance and the tack holes that are left are a disadvantage.

METAL WEATHER STRIPPING.

Metal weather stripping has shown itself a very efficient means of reducing crack leakage and thus a material aid in making a house weather tight. It is now obtainable in a variety of forms. To install it the window sash must be removed and grooves cut to receive the metal strips. When the work is properly done most of the stripping is hidden and the exposed part has a neat appearance. The work is usually done by an experienced workman, although handy men sometimes buy the stripping and install it themselves. Metal weather stripping should be permanent; it should allow easy movement of sashes and at the same time effectually prevent the passage of air. Atmospheric conditions causing swelling or shrinkage of frames should have no effect upon its behavior. While beneficial results from it are recognized, the greater cost limits its use.

CALKING MATERIALS.

Calking compounds are used to insure against air leakage between the window or door frames and the stone, brick, or concrete of the building. Temperature, moisture, and indeterminate causes make for expansion, contraction, and settling. A joint of cement, mortar, or other solid material is hardly practical. The space may be closed with oakum or other calking material forced into the opening. A good calking compound for this use should have the property of expanding as the crevice widens and contracting as the crevice narrows.

LEAKY FLOORS WASTE HEAT.

Uninsulated floors will cause waste of heat. Moreover, cold drafts sweep across them, making the room an unfit place for anyone to sit. Cellars are the best guarantee of warm floors, but, if conditions make it difficult or perhaps impossible to have a cellar, a coat of plaster between the rough and finished flooring will help to make a very tight and warm floor. Heavy insulating paper can be used with the same result, and sealing the joints with lath and plaster or wall board will do.

PIPES AND HOT-AIR DUCTS SHOULD BE INSULATED.

Another important aid in economizing heat is the insulation which should be provided for the steam or hot-water pipes or warm-air ducts. Standard makes of pipe coverings will effect a saving in coal. By all means cover all pipes that are in exposed positions. In one home where hot-air ducts were placed against the north wall no heat could be obtained from the register until the space around the duct was packed with insulating material.

EFFECT OF CRACK OPENINGS IN WINDOW LEAKAGE.

The clearance between window sashes and frames and between doors and frames varies from $\frac{1}{16}$ to $\frac{3}{32}$ inch; in poor construction the opening may be as much as $\frac{1}{8}$ to $\frac{1}{4}$ inch. A clearance of $\frac{3}{32}$ inch is quite usual. With a wind velocity of 15 miles per hour this opening of $\frac{3}{32}$ inch would permit the passage of about $1\frac{1}{2}$ cubic feet of air every minute for every linear foot of crack around the window. An ordinary double-sash window (36 inches wide by 72 inches high) would admit about 30 cubic feet of air per minute. With $\frac{1}{16}$ inch clearance 20 cubic feet per minute would be admitted.

The effect of this leakage upon the heating of the room may be serious. A room 10 feet wide by 20 feet long, with a ceiling 10 feet high, contains 2,000 cubic feet of air. Assuming that the longer side is exposed to the north or west, and that there are two windows with $\frac{3}{32}$-inch clearances, and assuming that the air is to be changed completely once each hour, which is customary for residential plants, it would require 2,900 heat units to raise the temperature from 0° to 70°, with the wind blowing at 15 miles per hour. The air leakage through the clearances around the sash would be about 3,650 cubic feet per hour, or one and eight-tenths times the cubical measurement of the room. To heat this quantity of air about 5,300 heat units would be required, or approximately 80 per cent more than that required for one complete change of air per hour. If the wind velocity be 30 miles per hour the leakage would be doubled and there would be required three and one-half times the number of heat units needed for one complete change per hour.

Tightly fitting windows will improve these conditions. If the crack opening were one-sixteenth inch, then, instead of 80 per cent more than the designed capacity being required, the additional heat units would be about 22 per cent.

The advantage to be derived from good construction will be appreciated in the comfortableness of the room and realized in the fuel saving. More fuel is invariably consumed in a house with loosely

fitted windows than in one where the clearance is reduced to a minimum. Increased fuel consumption is seldom adequate to correct faulty construction, particularly on windy days.

EFFECT OF USING METAL WEATHER STRIPPING.

As pointed out, tight-fitting windows are essential if leakage losses are to be kept down. Ordinary felt weather stripping helps to reduce this loss. Metal weather stripping is still better and aids materially toward an annual saving of fuel. Some tests have demonstrated that it is possible, by the use of metal weather strip, to reduce by 88 per cent the leakage through a one-thirty-second inch crack with a wind velocity of 15 miles per hour and by 83 per cent with a 30-mile wind.

The condition of the windows in a building, whether tight, loose, or loose enough to rattle, plays a very important part not only in the comfort derived from a heating plant but more noticeably in the annual cost of operation. Suitable metal weather stripping frequently reduces by 15 to 20 per cent the radiation required.

The prevention of window leakage means a saving of heat and a lessening of dirt blown into the house. In a certain apartment house, situated near a railroad station in a large city, during the first season of its occupancy the heating system supplied sufficient heat with a reasonable economy of fuel, but smoke and dust were a nuisance. Metal weather stripping was applied before the next heating season, and as a result the temperature of the rooms was too high. The radiating surface was reduced almost one-fourth, and it still supplied sufficient heat, while the fuel consumption also showed a noticeable reduction. Fuel saving of 15 to 25 per cent appears possible by equipping windows and doors with metal stripping. If, therefore, metal weather stripping is put in when the house is built, it is possible to reduce the size and cost of the heating plant proportionately to the reduction in radiation surface made possible. The cost of metal weather stripping may frequently be offset by the reduction in cost of the heating plant.

HUMIDITY.

It is now recognized that in addition to maintaining the proper temperature in an artificially heated house another factor of great importance is humidity, or the moisture that is present in the air. All air contains moisture in varying amounts, depending upon locality and temperature.

The rate of evaporation from the body determines susceptibility to heat and cold. Temperature and humidity largely determine this. In the southwest section of our country, where the air is relatively

dry, the evaporation, being high, produces a cooling effect and we are able to stand a comparatively high temperature. In the north middle section, where the relative humidity is comparatively high, a very low temperature is far less objectionable than where the temperature and humidity are both low, for in the former case high humidity hinders bodily evaporation, and therefore lessens the cooling effect, while in the latter the cooling effect of evaporation augments that due to the low temperature. A pleasant and healthful atmospheric condition should be our aim, and this may be secured by reproducing as nearly as possible within our houses one that approximates a proper humidity for the temperature maintained.

Open windows at night cause a higher average humidity in the house. This produces a soothing effect upon tired nerves, supplies more healthful air, and causes dust to deposit on the floor instead of floating to be breathed. One hundred years ago 50° to 55° was considered a good house temperature. Fireplaces were used then. During the era of stoves, about 70 years ago, 62° was considered satisfactory. Thirty years ago, with furnaces in greater use, a temperature of 72° was maintained, while now a temperature of 70° is considered standard, although it is not unusual to find steam-heated homes maintained at temperatures still higher. Dry air is likely to be dusty air. Dusty air is an irritant. Notice the dust betrayed by a sunbeam. When air within a house is heavily laden with dust the relative humidity is most likely to be very low. The floating particles are carried into the lungs. It were better to deposit these impurities on the floors and furniture. By increasing the relative humidity of dusty air in a room from 25 to 50 per cent, the floating particles in the air may be materially reduced. The best conditions of temperature and moisture for health have not as yet been definitely established. It is not unlikely that varying degrees of each, somewhat approximating outdoor conditions will be found best. At present some authorities state that a temperature of 68° F. with relative humidity between 40 and 50 per cent is about right. O. W. Armspach [1] from a comparison of 3,612,000 deaths with the corresponding weather conditions in the cities where the deaths occurred, has prepared a curve showing the proper temperature to be maintained for various percentages of humidity. The curve is reproduced in figure 8. Mr. Armspach says:

> The ideal temperature [wet-bulb] for physical health lies between 57 and 61°. Any variation above or below this limit has a marked effect upon health, a variation of 2° resulting in an increase in deaths of about 2 per cent.

A dry-bulb temperature of about 70° and relative humidity approximating 20 per cent—a condition that is not unusual in many

[1] Author of The Relation of Wet Bulb Temperature to Health published in the Journal of the American Society of Heating and Ventilating Engineers for May, 1920.

homes in winter—corresponds to a wet-bulb temperature of 50½°, and according to Mr. Armspach increases the death rate about 6 per cent above what it would be if the wet-bulb temperature were 57°.

RELATIVE HUMIDITY.

The moisture-carrying capacity of air depends on its temperature. Warm air has a much greater capacity for moisture than cold air, although it may feel drier. It is the relation between the actual amount of moisture in the air at a given temperature and the amount of moisture that the air could hold at that temperature that causes it to feel dry or moist.

Consider a piece of cloth held in a vertical position and sprinkled with water. No water will drip from the cloth until it is completely saturated, holding all the water that it is capable of holding. So it is with air. When the air is so laden with moisture that water is deposited in the form of dew the air has reached the point of complete saturation, known as the dew point. Then the relative humidity is 100 per cent. If air contains seven-tenths as much water as is present when it has just reached the dew point, its relative humidity is 70 per cent. If a room having a temperature of 40° with air at 70 per cent relative humidity be warmed up to 70°, the percentage of saturation decreases with the increase of temperature, since the warmer the air the more moisture it is capable of holding in suspension. Unless more moisture is added as the temperature is increased the percentage of saturation will be reduced, so that whereas the air at the lower temperature held seven-tenths as much as it was capable of holding, under the higher temperature it holds only two-tenths as much. Then its relative humidity would be 20 per cent.

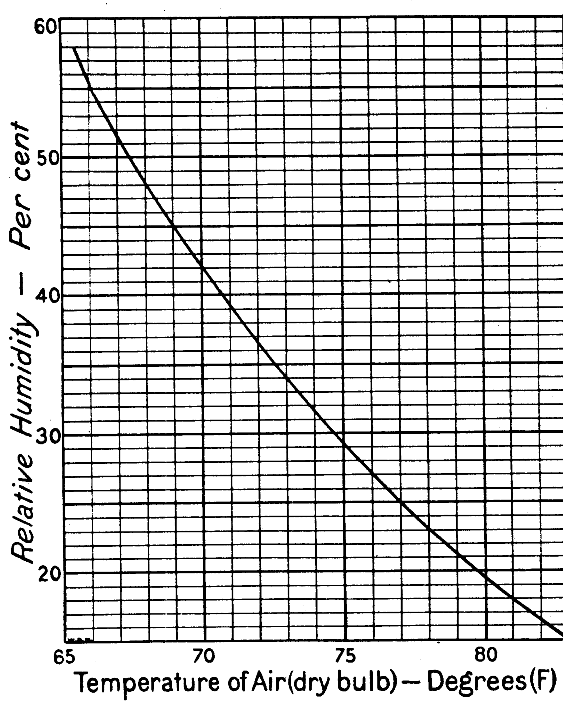

FIG. 8.—Temperature-humidity curve.

There is little doubt but that in most dwellings during the heating season the air is drier than is best for health and comfort. The relative humidity is too low. A room in which the air is properly humidified will be more comfortable at a lower temperature than one in which the moisture content is too low.

Our bodies are cooled by evaporation from them. If the body be surrounded by very dry air evaporation will take place rapidly and produce a cooling effect so that a person feels cold. If the body be surrounded by moist air evaporation takes place more slowly, the rate of evaporation is less, and a person feels warm though the actual temperature of the air may be lower. Too much moisture with heat is equally unpleasant, producing a muggy feeling, quite noticeable in some parts of the country where high humidity with high temperature prevails for long periods.

It is not believed that any investigations have proved definitely what are the best conditions as to temperature and moisture for our dwellings. Seventy degrees F. is generally taken as the standard temperature for living and other rooms in which the occupants are inactive, excepting sleeping rooms. It is thought that for this temperature a humidity between 40 and 50 per cent should be maintained. It should not be less than 30 per cent, whereas it is probable that were the humidity in our houses tested it would be found usually to be 20 per cent or lower. That is as dry as desert air and predisposes persons that breathe it to throat and nose irritations. The drier the air the more difficult it is to heat a house with it. The moisture in the air carries and retains heat. In cold weather a considerable quantity of moisture is required if the humidity is to be kept up.

MOISTURE REOUIRED TO MAINTAIN HUMIDITY.

Consider an average-sized house containing a family of five persons. Each person requires 1,800 cubic feet of air per hour; so 9,000 cubic feet ($5 \times 1{,}800$) must be provided for the occupants every hour. Cracks around windows and doors or the opening of doors and windows are usually depended upon to supply the needed air where a steam or hot-water heating system is installed. If a warm-air pipe furnace is used the fresh-air duct will take care of it. If air at 0° temperature and 70 per cent relative humidity is introduced into a house and heated to 70° F. and during the temperature rise no moisture is added the relative humidity will decrease 65.91 per cent to 4.09 per cent. That is entirely too low.

Assume that the temperature is to be maintained at 70° F. and the relative humidity at 40 per cent, which is not too high. In order that those values be kept for 9,000 cubic feet per hour there would

be required an evaporation every hour of almost one-half gallon of water. Not many existing plants are capable of approximating that quantity.

HOW TO DETERMINE HUMIDITY IN A ROOM.

A rough practical test for determining whether the air in a room is too dry is to observe the inside of windows on a cold day. If frost forms freely on the inside of the glass there is no doubt but that the inside air has sufficient humidity. If there is no sign of frost the air is likely too dry.

If a more accurate test is desired it may be performed with two thermometers in the following manner: Use thermometers that have their bulbs completely exposed. Around the bulb of one tie a small piece of cheesecloth or other porous fabric and thoroughly saturate it with water. Whirl this wet-bulb thermometer around on the end of a string 12 to 15 inches long. The height of the mercury in this thermometer will fall rapidly, owing to the evaporation of the water from the little sack surrounding the bulb. The drier the air the faster the mercury will fall. After two or three minutes, the wet-bulb temperature will become stationary. A reading should be taken instantly to obtain the low point. The dry-bulb thermometer reading should be taken simultaneously. Subtract the wet-bulb reading from the dry-bulb reading and refer to the accompanying table, from which a value for the relative humidity may be obtained.

The experiment can be performed with one thermometer by taking the average room temperature before using it as a wet-bulb thermometer.

TO USE THE TABLE.

Suppose, with the dry-bulb temperature at 70° F., that the wet-bulb temperature became stationary at 56° F. The difference between the two is 14°. Refer to the table and follow down the first column on the left to 70, then follow the horizontal line until the vertical column 14 is reached, and read the relative humidity, 40 per cent. For ordinary living rooms with temperatures of 68° or 70° the relative humidity should be between 30 and 50 per cent.

With the help of the table it should be an interesting experiment to determine the temperature to be maintained when the humidity is about what it should be; 40 per cent might be taken as a standard to work toward. Very probably the temperature in many houses has been maintained at 70° and above when it could be lowered were the relative humidity kept up to the proper value.

Reading of dry bulb thermometer (degrees F.).	Difference between dry and wet bulb (degrees F.).																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Relative humidity (per cent.).																				
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1
61	94	89	84	78	73	68	63	58	54	49	44	40	35	31	27	22	18	14	10	7	3
62	94	89	84	79	74	69	64	59	54	50	45	41	36	32	28	24	20	16	12	8	4
63	95	89	84	79	74	69	64	60	55	50	46	42	37	33	29	25	21	17	13	10	6
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30	26	22	18	15	11	7
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32	29	25	21	17	14	10
67	95	90	85	80	75	71	66	62	58	53	49	45	41	37	33	30	26	22	19	15	12
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	31	27	23	20	16	13
69	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	32	28	24	21	18	14
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15
71	95	90	86	81	77	72	68	64	60	56	52	48	45	41	37	33	30	27	23	20	17
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38	34	31	28	24	21	18
73	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39	35	32	29	25	22	19
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39	36	33	29	26	23	20
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41	38	34	31	28	25	22
77	96	91	87	83	79	74	71	67	63	59	56	52	48	45	42	39	35	32	29	26	23
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33	30	27	24

[Table based on 30 inches barometric pressure.]

SUPPLYING MOISTURE TO THE AIR.

Aside from the increased comfort and healthfulness secured from properly moistened heated air the saving in fuel through moistening should not be overlooked. It is estimated that 25 per cent of the cost of heating is expended in raising the temperature within a house from 60° to 70°. The conclusions of Mr. Armspach indicate that the best temperature for physical health lies between 57° and 61° (wet bulb) provided the relative humidity is maintained between 65 and 75 per cent. If his conclusions be correct, then it is possible to save fuel and yet be comfortable at a temperature below that commonly thought to be required. To do so, however, means must be provided for evaporating more water. To do this requires either a large evaporating surface, a high temperature, or both.

There are several methods by which moisture may be added to the air supply of a warm-air furnace-heating system, although it is doubtful whether any at present are capable of supplying sufficient vapor to maintain high enough relative humidity to permit a room temperature much below 70°. The common practice of placing a small cast-iron receptacle, called the water pan, in the side of the furnace casing is but a feeble effort in the right direction. It is seldom, if ever, large enough or has sufficient surface, while in many cases the pot is so placed that no appreciable amount of water can be added to the passing air. A small water pan set low down in the furnace has practically no effect. It should have a large area and be set well up into the warm-air space, so as to

make evaporation as rapid as possible. The pan should be heavy enough to stand rusting. It should be placed over the combustion chamber with its bottom at least 2 inches above the top. A supply pipe with ball stopcock and an overflow pipe make it easy to keep the pan filled with water. With a pressure water system automatic control is possible; the quantity of water evaporated increases with the quantity and temperature of the air passing through the furnace, so that the humidifying apparatus to some extent is self-regulating. A very effective pan may be made by riveting and soldering a strip of galvanized iron around the inside of the top casing directly under the openings for hot-air leader pipes. The ring should be from 2 to 2½ inches wide, with the inside edge turned up about three-quarters of an inch. A little cup riveted on the outside of the casing with small holes drilled through the casing permits hand filling, or a permanent supply pipe can be connected.

If there is a cold-air chamber a satisfactory humidifier may be provided by building a galvanized iron and wire rack with two or three sloping shelves to hold crushed coke. Insert a perforated pipe so that small streams of water will play upon the coke on the top shelf and trickle down through the ones below, thus keeping the coke continually wet. A drip pan at the bottom connected with an overflow pipe leading to a drain completes the apparatus. Another method is to spray the incoming air by means of several small atomizers arranged in the cold-air duct with a proper outlet for the overflow. Moist air absorbs heat better than dry air; otherwise it makes little difference whether the air is moistened before or after it is heated. Several commercial humidifiers for spraying the heated air as it leaves the furnace are also obtainable. Very satisfactory humidification has been secured with the better types.

So far as known no one has yet devised a satisfactory method of moistening air in houses heated by hot water. Pans which hang on the back of the radiator are obtainable, but they do not have a large surface, and as they are not highly heated they are not very effective. Sheets of asbestos or blotting paper placed directly beneath the pans with one or more needle holes punched in the bottom adds to their effectiveness, as the paper absorbs the water and increases the evaporating surface. The objection to this arrangement is inability to control the flow of water. Wicks or an apron of absorbent material hanging down back of the radiator with one end resting in the water pan will draw up water by capillary attraction, and the air movement around the radiator will evaporate it and carry it off into the room.

Water pans are little more effective with steam than with hot-water radiators. Provision is sometimes made to discharge steam

slowly into the room direct from the radiator. This proves much more effective where there is steam pressure, but many dislike the noise and odor of the escaping steam.

VENTILATION REQUIREMENTS.

Air confined within an occupied room or building becomes foul and unfit for breathing. Fresh air is necessary to sustain life. Ventilation consists in the natural or mechanical displacement of vitiated air and its replacement by fresh air. Complete renewal of air can not correctly be said to occur any given number of times in an hour, since a total change does not actually occur. What does happen is that the incoming air mixes with and dilutes the foul air to a point suitable for healthful respiration.

When air is taken into the lungs it has the temperature of the room, but when expired its temperature is 90° to 98°. It is also nearly saturated with water vapor and is from 1 to 3 per cent lighter. These, however, are not the greatest changes. Air is composed essentially of oxygen, nitrogen, and very small proportions of carbonic acid gas and water vapor. The proportion of carbonic acid is 2 to 4 parts in 10,000. The amount of water vapor is greater in proximity to a body of water and varies with the temperature. Oxygen is the life-sustaining element of the air. Nitrogen dilutes it.

Carbonic-acid gas or carbon dioxide in itself is not dangerous to health, but when carbon dioxide is exhaled, other gases that are harmful are given off at the same time and it is these that may prove a menace to health. The carbon dioxide serves more or less as an indicator of the presence of the real danger. If carbon dioxide is present in the air in considerable quantity, dullness, headaches, and fainting are liable. As air is exhaled the gases diffuse, and the carbonic acid is soon distributed quite uniformly throughout the air of a room, thereby increasing the content to more than 4 parts in 10,000. When the proportion of carbonic acid gas goes up to 7 parts in 10,000 the effect of poor ventilation is felt, and when 10 parts is reached actual discomfort may occur. The carbonic acid content should therefore be kept below 6 or 7 parts in 10,000 by ventilation. As much as 1,800 to 2,000 cubic feet of fresh air is necessary for each occupant every hour to control the carbonic-acid content.

METHODS OF VENTILATING.

Mechanical means of ventilation are required for buildings of considerable size. Residences or small buildings may be provided with foul-air flues or with a ventilating chimney. One-story buildings in which there is one large main room may have a galvanized-iron or copper ventilator in the roof through which obnoxious gases will be drawn away.

For houses of certain types a ventilating chimney when used in connection with a hot-air furnace will give excellent results. In place of the ordinary brick flue a large shaft is erected through the center of the house. Through the middle of this stack is run the smoke pipe, which for low buildings may be of terra-cotta pipe tightly cemented at the joints. A wrought-iron stack is preferable. This stack rests on a cast-iron bed plate supported by a brick pier and should be properly anchored and stayed with iron braces in the brick-work every 8 or 10 feet. A heavy galvanized-iron hood supported by upright iron standards should be mounted on top of the stack. The smoke pipe should be built up and braced as the stack is erected, and frames for the foul-air registers should be set into the stack from the different floors at the same time. The heat from the smoke pipe or flue will expand the air in the ventilating shaft, causing an upward movement of the air that will exhaust the foul air from each room connected with it.

If a central ventilating shaft is not feasible other means should be devised to allow the escape of air from the various rooms, for fresh warm air can not enter unless it displaces an equal volume of room air. That is sometimes the cause of a room not heating.

A fireplace is a very good form of foul-air flue, and if the house has several fireplaces no other foul-air flues are necessary. If several rooms open into one in which there is a fireplace this is generally sufficient for all the rooms. All fireplaces should have dampers so as to assure positive regulation as a vent flue.

Cracks around the windows and doors often serve to allow air to escape, but not if they are on the windward side. Sometimes it is well to provide either a recirculating duct or foul-air flues in the inside partitions. The foul-air registers are then placed at the baseboard, for the hot air enters the room opposite the windows, rises to the ceiling, and passes along it to the windows, where it is cooled, drops to the floor, and passes along it to the foul-air register. The hot-air register should be so located with respect to the foul-air return register that there will be no danger of the hot air passing directly to the return-air flue.

A return flue should not be placed in the bathroom, kitchen, or bedrooms on account of the danger of conveying unpleasant odors or disease germs through the house by means of the recirculated air. It is well to install in the bathroom and kitchen, vents to the outside air which can be opened or closed. A foul-air flue may be provided by using the space between the studding and properly installing a wall stack, such as is used for carrying heated air to second-floor rooms in a warm-air furnace installation, with a register face in the baseboard and terminating at the top in a roof ventilator. Such flues should not come into direct contact with any woodwork, and all

adjacent woodwork should be carefully protected with fireproof material. A ventilating flue for the kitchen should open near the ceiling and preferably over the cook stove so as to carry off the fumes and odors. If flues for several rooms are installed they may all be led to one large roof ventilator, but there should be no opening between the flue entrance and the discharge side of the ventilator. To secure positive action, the vent flue from the kitchen and bath should be built within the chimney, so that the heat from the smoke pipe will assure it a draft. Care should be taken not to connect two rooms to the same studding space. Where the slight additional cost need not be considered, it is better to connect each flue separately with the ventilator.

Where residences are heated by means of warm-air furnaces considerable saving in fuel is possible by means of a recirculating duct. Separate ducts from each room except those likely to contain obnoxious gases may be installed so as to empty into a larger one which discharges into the cold-air shoe at the base of the furnace or into the cold-air duct between the outside opening and the cold-air pit. A more common method is to build one large recirculating register in the lower hallway, either in the floor or wall, through which all the air within the house may be led back to the furnace. The saving in fuel consumed is directly proportional to the comparative volume and temperature of this air to the total quantity delivered into the rooms for heating purposes. All recirculating ducts should have dampers where they enter the unheated air-supply chamber.

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